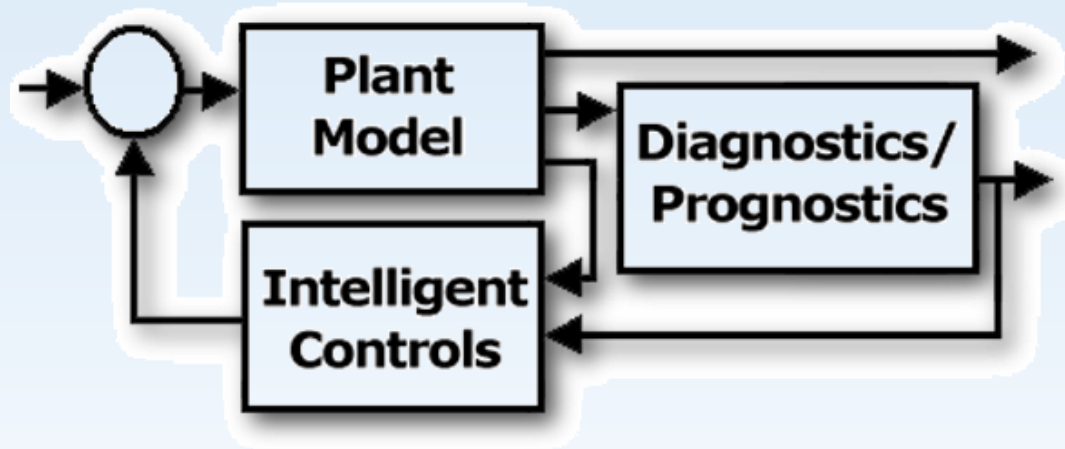


NASA GRC Aero-Propulsion Control Research - Overview



5th NASA GRC PCD Research Workshop
Sept. 16-17, 2015, Cleveland, OH

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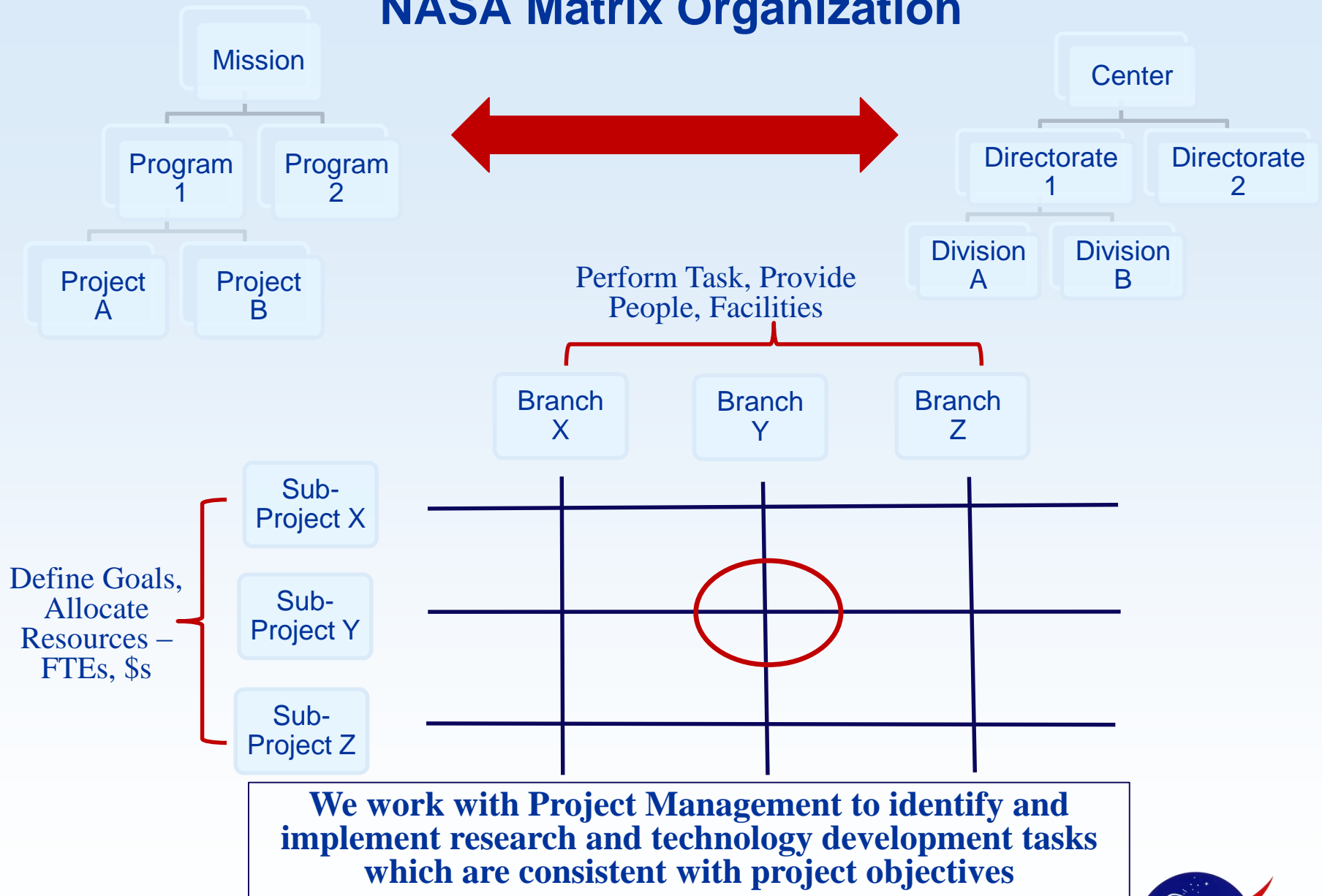
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NASA Matrix Organization



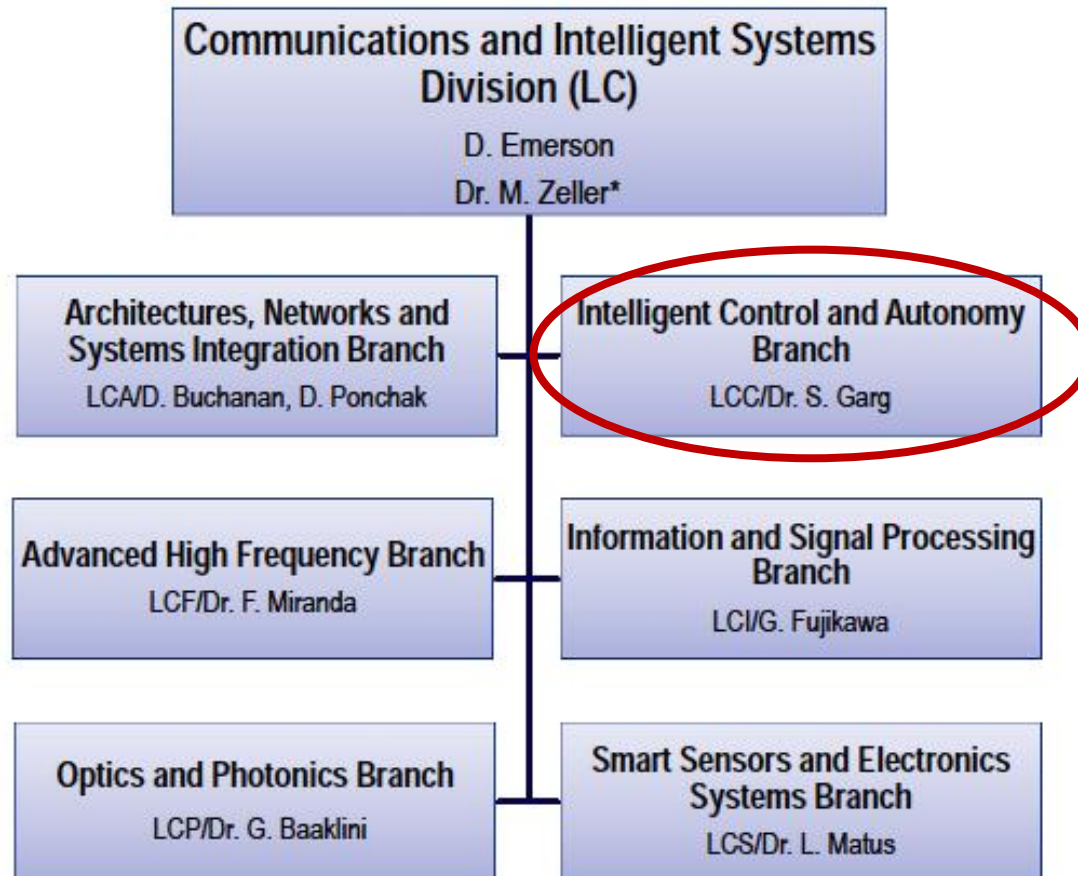
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Communications and Intelligent Systems Division (LC)



**Acting*

ICAB Overview

- Mission

- Research, develop and verify aerospace system dynamic modeling, health management, control design and implementation technologies that provide advancements in performance, safety, environmental compatibility, reliability and durability. Major focus is on technologies for aeropropulsion systems.
- Facilitate technology insertion into the mainstream aeropropulsion community

- Capabilities

- 31 engineers and scientists including 17 permanent civil servants, 3 pathways interns, and 11 contractors - most with advanced degrees and extensive experience in controls related fields
- Extensive computer-aided control design and evaluation facilities including real-time and man-in-the-loop simulation facility
- Strong working relationship with controls technology groups in the aerospace propulsion industry, academia and other agencies
- Strong multidisciplinary efforts in collaboration with other Branches within LC, and with groups in LT

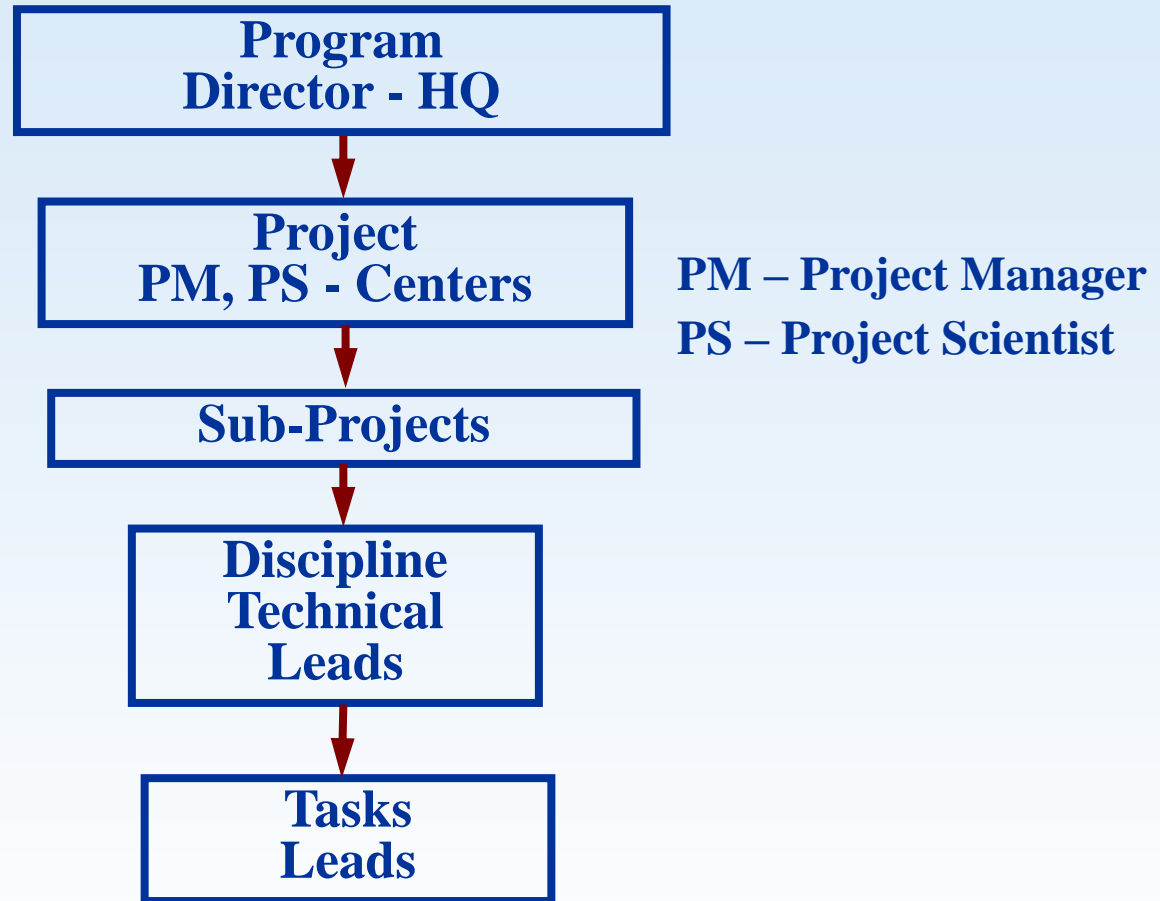
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NASA ARMD Management Structure



- **Each Center: AFRC, ARC, GRC, LaRC; has a center Point of Contact (PoC) who coordinates with Program Directors and Project Managers**
- **Line Management coordinates with Discipline Technical Leads**

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Aeronautics Strategic Research Thrusts



Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks



Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard



Ultra-Efficient Commercial Vehicles

- Pioneer technologies for big leaps in efficiency and environmental performance



Transition to Low-Carbon Propulsion

- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology



Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system



Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications



How are the vision's research thrusts used?

All of the new programs address more than one, or all, of the research thrusts.

MISSION PROGRAMS

Airspace Operations
and Safety Program



AOSP

**Safe, Efficient
Growth in Global
Operations**

**Real-Time System-
Wide Safety
Assurance**

**Assured Autonomy
for Aviation
Transformation**

Advanced Air Vehicles
Program



AAVP

**Ultra-Efficient
Commercial Vehicles**

**Innovation in
Commercial
Supersonic Aircraft**

**Transition to Low-
Carbon Propulsion**

**Assured Autonomy for
Aviation Transformation**

Integrated Aviation
Systems Program



IASP

**Flight research-
oriented, integrated,
system-level R&T
that supports all
six thrusts**

**X-planes/
test environment**

SEEDLING PROGRAM

Transformative
Aeronautics Concepts
Program



TACP

**High-risk, leap-frog
ideas that support all
six thrusts**

**Critical cross-cutting
tool development**

NASA Aeronautics Program Structure

Effective FY15

Aeronautics Research Mission Directorate

Mission Programs

Seedling Program

Advanced Air
Vehicles (AAVP)

Airspace Operations
And Safety (AOSP)

Integrated Aviation
Systems (IASP)

Transformative Aeronautics
Concept (TACP)

Advanced Air
Transport Technology
AATT - (GRC)

Airspace Technology
Demonstration
ATD - (ARC)

Environmentally
Responsive
Aviation
ERA - (LaRC)

Cross Program
Operations
CPO - (ARMD)

Revolutionary Vertical
Lift Technology
RVLT - (LaRC)

SMART NAS – Testbed
for Safe Trajectory
Operations (ARC)

UAS Integration
in the NAS
(AFRC)

Leading Edge
Aeronautics Research
for NASA
LEARN - (ARMD)

Commercial Supersonic
Technology
CST - (LaRC)

Safe Autonomous
System Operations
SASO - (ARC)

Flight Demonstration
and Capabilities
FDC - (AFRC)

Transformative Tools
and Technologies
TTT - (GRC)

Advanced Composites
AC - (LaRC)

Aeronautics Evaluation
and Test Capabilities
AETC - (ARMD)

Convergent Aeronautics
Solutions
CAS - (GRC)

GRC “Aero Controls” Tasks

Advanced Air Vehicles Program

- AATT – Dynamic Systems Analysis Tools and Methods
- AATT – Turbine Tip Active Clearance Control
- CST – Aero-Propulso-Servo-Elasticity
- CST (AFRL) – Combined Cycle Engine Modeling and Control

Airspace Operations and Safety Program

- ATD – Propulsion Simulation for Enhanced Simulator Fidelity
- SMART NAS – Runtime Assurance for Advanced Controls

Transformative Aeronautics Concept

- TTT – Distributed Engine Control Tools and Technologies
- TTT – Model Based Engine Control
- TTT – Active Combustion Control
- TTT – *Modeling of Unsteady Combustion Systems*
- CAS – Gas Path Health Management

Other

- Enhanced Engine Response Control – discontinued after VSST
- Engine Simulations: C-MAPSS, C-MAPSS40k, T-MATS
- Engine Icing – detection and mitigation

Opportunities

Significant Opportunities as programs/projects get reformulated:

- **Hybrid-Electric Propulsion** – Dynamic modeling and control of power generation system, integrated modeling of propulsion+power system
- **Autonomy** – Intelligent Propulsion Control and Health Monitoring
- **Compact Gas Turbine** – active turbine tip clearance control, dynamic modeling of advanced concepts
- **Engine Icing** – use of engine control sensors for engine icing detection, and mitigation through control

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Engine Simulation Software Packages

The following engine simulation software packages, developed in Matlab/Simulink and useful for propulsion controls and diagnostics research, are available from NASA GRC software repository

- **C-MAPSS** – Commercial Modular Aero-Propulsion System Simulation
 - Simulation of a modern commercial 90,000 lb thrust class turbofan engine with representative baseline control logic:
<http://sr.grc.nasa.gov/public/project/54/>
- **C-MAPSS40k**
 - High fidelity simulation of a modern 40,000 lb thrust class turbofan engine with realistic baseline control logic:
<http://sr.grc.nasa.gov/public/project/77/>
- **T-MATS** – Toolbox for Modeling and Analysis of Thermodynamic Systems
 - An open source Simulink toolbox intended for use in the modeling and simulation of thermodynamic systems and their controls.
<https://sr.grc.nasa.gov/public/project/91/>

Additionally, a one hour educational video on “Fundamentals of Aircraft Engine Control” is available at:

<http://mediaex-server.larc.nasa.gov/Academy/SilverlightPlayer/Default.aspx?peid=135553bc3b7b4171b7c54ee0578489211d>

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“Controls” Technologies Available for Licensing

NASA GRC Technology Transfer Office provides information on partnering with NASA including technologies available for licensing:

<http://technology.grc.nasa.gov/>

Following are some GRC developed “controls” technologies listed as available for licensing:

- **Optimized tuner selection for engine performance estimation**
<http://technology.grc.nasa.gov/patent/GRC-QL-0022>
- **High speed idle engine control mode – patent pending**
<http://technology.grc.nasa.gov/patent/LEW-TOPS-55>
- **Atmospheric Turbulence Modeling for Aero Vehicles**
<http://technology.grc.nasa.gov/search/patent/turbulence>
- **Conditionally Active Min-Max Limit Regulators – patent pending**
<http://technology.grc.nasa.gov/patent/LEW-TOPS-56>

Collaboration Opportunities

- NRA (NASA Research Announcements)
 - Open to industry and universities
 - Very focused on specific topics
 - Announced by Projects on a periodic basis

<http://www.aeronautics.nasa.gov/nra.htm>
- SBIR (Small Business Innovative Research)
 - Open to small businesses
 - Very broad areas of call. Topics determined by Programs/Projects

<http://sbir.gsfc.nasa.gov/>
- Space Act Agreement – no direct NASA funding
 - Open to industry/universities/govt. agencies
 - Ideal for collaboration on mutual areas of interest without exchange of funds or with inflow of funds to NASA efforts
 - Opportunity for industry to leverage NASA investment in projects
- Student and Faculty Programs

<http://www.nasa.gov/centers/glenn/education/index.html>

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